Canal and Isthmus Debridement Efficacy Using a Sonic Irrigation Technique in a Closed-canal System

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Abstract

Introduction: This *in vitro* study compared debridement efficacies of a sonic irrigation technique (Vibringe; Cavex Holland BV, Haarlem, The Netherlands) with side-vented needle irrigation (SNI) in the mesiobuccal root of maxillary first molars. **Methods:** Twenty roots with narrow isthmuses ($\leq$1/4 canal diameter) were selected using micro–computed tomography scanning. Collagen solution was injected into canals/isthmuses and reconstituted with NH_4OH to simulate canal debris. Each root was sealed apically and embedded in polyvinyl siloxane simulating a closed-canal system. Canals were instrumented to size 40/.04 taper 1 mm short of the anatomic apex. The final irrigation was performed with the Vibringe or SNI. Roots were demineralized, sectioned at 6 levels (1.2–3.2 mm) from the anatomic apex, and stained using Masson trichrome stain. The areas occupied by canals and isthmus and the debris-containing areas were statistically analyzed with repeated-measures analyses using "irrigation technique" as the between factor and "canal level" as the within factor ($\alpha = 0.05$). **Results:** Canals had significantly more debris at 1.2 and 1.6 mm ($P < .001$), but there was no overall difference between the 2 techniques ($P = .561$). Significant differences were found between the Vibringe and SNI at 2.4, 2.8, and 3.2 mm ($P < .05$). There was no significant difference in the remaining debris in the isthmus for SNI at all ($P > .05$). Considerably more debris remained at 1.2 and 2.0 mm for the Vibringe ($P < .05$). A significant difference was observed between the canal and the isthmus ($P < .001$). **Conclusions:** There is no difference between the Vibringe and SNI in their overall debridement efficacy in apical one third of the mesiobuccal root of maxillary first molars. *(J Endod 2012;38:1265–1268)*

Key Words

Closed system, collagen, isthmus, side-vented needle, sonic irrigation

The elimination of pathogens from root canals is difficult, and current root canal treatment techniques are unable to consistently disinfect the canal space (1–3). Clinical studies have shown a 96% success rate for primary root canal therapy in vital teeth and an 86% success rate for teeth with pulpal necrosis and apical periodontitis (4, 5). Mechanical instrumentation of the canal space leaves a smear layer on the surface of intraradicular dentin, occluding the entrances to dentinal tubules and creating a niche from which residual microorganisms can thrive (6, 7). Retention of the smear layer when coupled with the irregular cross-section of the canal, the presence of canal fins, and the complex anatomy of the apical delta can adversely affect the outcome of root canal treatment (8–11). Instrumentation with nickel-titanium instruments alone does not completely eliminate the bacteria load or remove soft-tissue debris (12–14). Chemical debridement is paramount in ensuring that canals are sufficiently cleaned before obturation. For optimal chemical debridement, it is critical that irrigants are delivered as close to the apical stop as possible (15, 16).

Previous studies have used a collagen debris model to examine the effectiveness of irrigation techniques (17, 18); however, those studies were performed in straight, isthmus-free canals of single-rooted teeth. Various irrigation techniques have been found to be more effective than conventional needle irrigation in debris removal (19). When evaluating debris removal, the disinfection of lateral canals, and the removal of smear layers, sonic irrigation has been shown to be superior to conventional needle irrigation (20, 21). The Vibringe (Cavex Holland BV, Haarlem, The Netherlands) is a sonic irrigation system with a cordless handpiece that fits in a disposable 10-mL Luer-Lok syringe compatible with all irrigation needles (15).

The objective of the present study was to compare the debridement efficacies of a sonic irrigation system (the Vibringe) and side-vented needle irrigation (SNI) in the mesiobuccal (MB) root of maxillary first molars with narrow isthmuses at 1.2 to 3.2 mm from the apical stop using a closed-canal model. The null hypothesis tested was that there is no difference between sonic irrigation (the Vibringe) and SNI in their overall debridement efficacy in the MB root of maxillary first molars. To further analyze this, the following were tested: (1) there are no differences in the debridement efficacy of the 2 irrigation techniques in the apical one third of the canal and isthmus, and (2) there is no difference in the debridement efficacy between the canals or isthmuses for either irrigation technique.

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Materials and Methods

Extracted human maxillary first molars were collected with patients' consent under a protocol approved by the Georgia Health Sciences University Human Assurance Committee. The teeth were stored until use at 4°C in 0.9% sodium chloride containing 0.02% sodium azide to prevent bacterial growth. The MB roots were scanned with micro–computed tomography scans (Model 1174; SkyScan, Aartselaar, Belgium) to select 20 teeth with narrow isthmuses (22, 23). Only roots in which the mesiodistal isthmus width was less than one quarter of the diameter of the unshaped canals were selected. This selection criterion was only applicable to the canal levels from which histologic sections were subsequently prepared (ie, 1.2–3.2 mm from the anatomic apex). The 20 selected roots were randomly divided into 2 groups ($n = 10$). A custom-fabricated fixture to simulate a closed-canal system was used to facilitate a consistent irrigation protocol treated by a single operator (24). The details of this setup are included in the supplementary material. (Supplemental material is available online at www.jendodon.com.)

Experimental Groups

After access and before instrumentation, the canals were injected with reconstituted collagen to simulate canal debris. Briefly, a 10-mg/mL collagen solution in acetic acid was prepared and reconstituted into fibrillar collagen with 1% ammonia solution for 4 hours. The reconstituted collagen was fixed in glutaraldehyde overnight. The collagen solution was injected into the canal system and drawn apically using a vacuum apparatus. Results from the pilot study conducted confirmed the placement of the collagen solution. The MB canals were instrumented to size 40/.04 taper Profile Vortex rotary nickel-titanium instruments (Dentsply Tulsa Dental Specialties, Tulsa, OK) using a crown-down technique to a standard working length (WL) of 16 mm. Recapitulation was performed with a size 10 K-file (Dentsply Tulsa Dental Specialties), and patency was maintained throughout instrumentation. During instrumentation, the pulp chamber was flooded with 6% sodium hypochlorite (NaOCl) and was replenished with 1 mL fresh NaOCl after each instrument. After the use of the last rotary instrument, the smear layer was removed using 17% EDTA. The MB roots were then randomly divided into the following groups for the final step of the irrigation protocol using 6% NaOCl: group 1: the SNI delivery technique consisted of placing a 30-G Max-i-Probe side-vented irrigation needle (Dentsply Rinn, Elgin, IL) at 1 mm from the WL for a period of 2 minutes with simultaneous agitation (25, 26) and group 2: the Vibringe device was attached to a 30-gauge Max-i-Probe side-vented needle. The needle was placed 1 mm from the WL, and the device was activated while delivering irrigant for a period of 2 minutes. After completion of each irrigation protocol, each root was rinsed with sterile saline, dried with paper points, temporized, removed from the experimental setup, and stored in 10% formaldehyde.

Light Microscopy

All roots were completely demineralized in 10% by weight formic acid/sodium formate and embedded in paraffin wax. For each root, 0.69-μm-thick sections were prepared at 0.4-mm intervals beginning at 1.2 mm and ending at 3.2 mm from the anatomic apex (23). The sections were stained with Masson trichrome stain and digitally recorded with a light microscope (BX 51; Olympus America, Melville, NY) (22). Images taken from the 6 root levels were analyzed using Image J software (National Institutes of Health, Bethesda, MD). Outlines of the MB canals and the isthmus were traced to determine the surface area of the respective region. Areas occupied by stained debris were also outlined for each canal and isthmus level from which the percentage area occupied by debris was calculated.

Statistical Analysis

Repeated-measures analyses were used to investigate whether there was a difference between sonic irrigation (the Vibringe) and SNI in their overall debridement efficacy; whether there were differences between the 2 techniques in the debridement efficacy, specifically among the 6 levels in the canal and isthmus; and whether debridement efficacy differed significantly between the canals and isthmuses within each technique. Because of the highly skewed nature of the data, rank-based methods incorporating rank transform were used (27), with 1 within factor (canal/isthmus level) and 1 between factor (irrigation technique) for each repeated-measures analysis (28). Bonferroni adjustments were made so that the family-wise error rate for the tests of each factor could be controlled at the 0.05 level (28). Unless otherwise specified, 2-tailed tests with $\alpha = 0.05$ were used for all comparisons.

Results

Figure 1 contains representative images that show different extents of canal and isthmus cleanliness at selected canal/isthmus levels using needle or sonic irrigation. Figure 2 summarizes the percentage area occupied by debris in the canals of the 2 experimental groups. Figure 3 summarizes the percentage area occupied by debris in the isthmus of the 2 experimental groups.

An analysis of the data from the canals showed no significant difference between techniques among the 6 canal levels ($P = .712$), so the main effects were analyzed. The irrigation techniques did not differ significantly ($P = .561$), but there was a significant level effect ($P < .001$). An analysis of the data from the isthmuses indicated that there was a significant difference between the irrigation technique and the level for the debridement efficacy data in the isthmus ($P = .013$). Comparing irrigation techniques at each level, significant differences were found between the Vibringe and needle irrigation at 2.4, 2.8, and 3.2 mm in that the Vibringe removed significantly more debris at these levels than needle irrigation.

With respect to whether debridement efficacy differed significantly between the canals and isthmuses for either technique, there was no significant difference in debris removal between the irrigation technique and the level ($P = .110$), but there was a significant difference between the canal and the isthmus ($P < .001$). Details of the statistical methods and results are included in the Supplementary Material (Supplemental Material is available online at www.jendodon.com).

Discussion

Incomplete chemomechanical debridement in root canals can leave residual bacteria, which contributes to failure in both primary and secondary root canal treatment (4, 5, 29–31). Thus, the use of appropriate antimicrobial disinfectants and their most optimal modes of delivery to the apical stop are issues that have stimulated intense *in vitro* and *in vivo* research in endodontics, resulting in the introduction of many devices that claim effectiveness in enhancing canal debridement (26, 32–34).

In this study, the canals and isthmuses were analyzed as separate entities when comparing irrigation techniques to determine if there was a difference in debridement efficacy. Canal cleanliness for the SNI control and the Vibringe was not significantly different. Both techniques removed significantly more debris at levels 2.0 to 3.2 mm. Conversely, isthmus cleanliness for SNI and the Vibringe was significantly different.

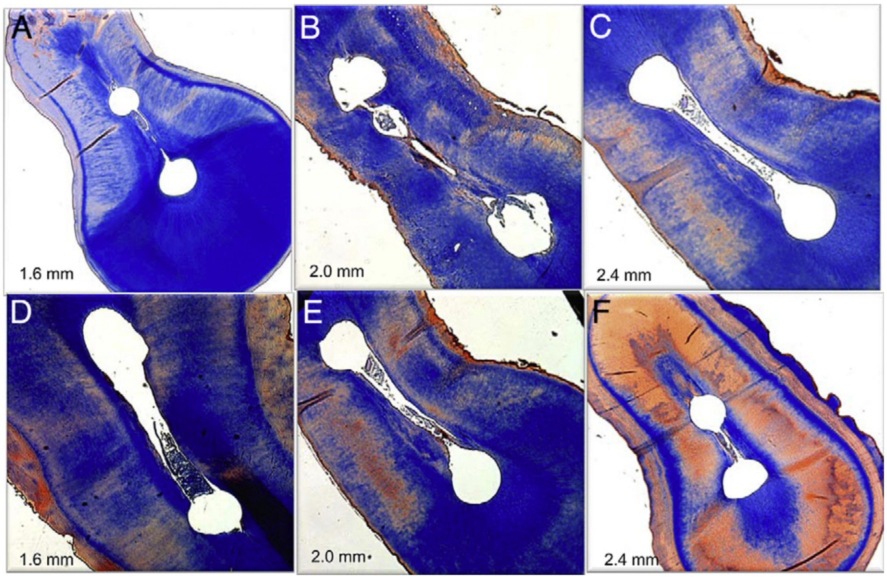

Figure 1. Light microscopy images of Masson trichrome–stained cross-sections of root specimens. Images shown represent selected specimens in each group at various root levels from the apical stop. (*A–C*) Specimens from the SNI group. (*D–F*) Vibringe group specimens (original magnifications 10×).

The Vibringe removed significantly more debris in noninstrumented isthmuses at levels 2.4 to 3.2 mm.

Based on the results of this study, one may conclude that the sonic irrigation device has a significantly better debridement efficacy than the more economic method of irrigating instrumented canals in multirooted teeth with conventional side-venting needles. Although the canal and the isthmus and different levels of the canal or isthmus space can be isolated in statistical analysis, it has to be stressed that they remain an integral part of the root canal system. The incomplete elimination of microorganisms that reside within the isthmus will eventually spread to the canals in the absence of a 3-dimensional seal. The same applies to the different levels of the canal or isthmus space. Thus, we resorted to test whether there is a difference in the debridement efficacy between the canals or isthmuses for either irrigation technique by using the area under the curve to measure the overall debridement efficacy over all levels separately for each specimen. The 2 irrigation techniques did not differ significantly. A significant difference was only identified between the canals and the isthmuses. The analytic data succinctly revealed that both irrigation techniques achieved the same results in the MB root of maxillary molars.

Within the constraints of this *in vitro* closed-canal study design and the presence of a narrow isthmus within the MB root of maxillary molars,

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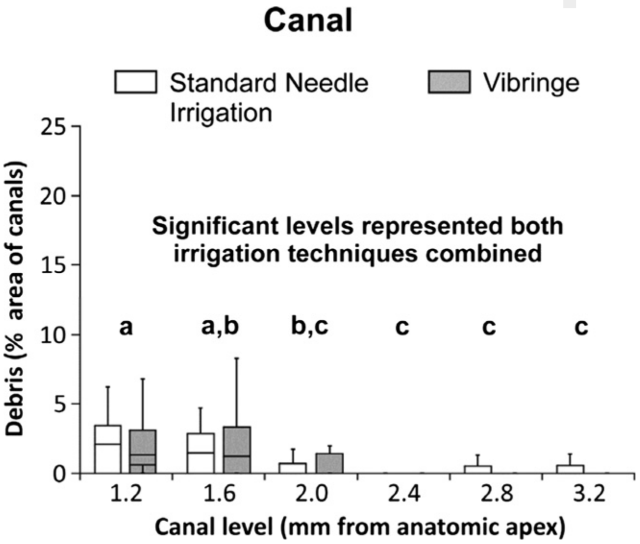

Figure 2. Box plots summarizing the extent of remaining debris expressed as a percentage of the total canal area at each canal level (ie, 1.2, 1.6, 2.0, 2.4, 2.8, and 3.2 mm) in the 2 irrigation groups. Each box plot represents the minimum value, 25th percentile, median, 75th percentile, and maximum value of a dataset. Significant levels represented both irrigation techniques (SNI and the Vibringe) combined. (There were no significant interaction between technique and level, so the main effects were analyzed.) Canal levels designated by the same lowercase letters are not significantly different ($P > .05$).

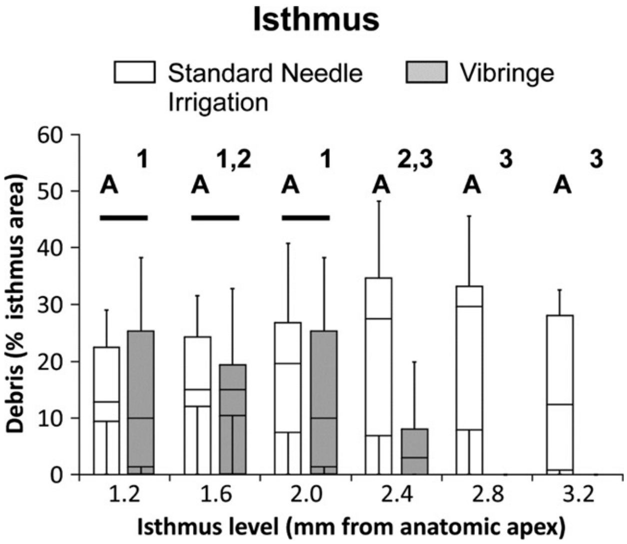

Figure 3. Box plots summarizing the extent of remaining debris expressed as a percentage of the total isthmus area at each isthmus level (ie, 1.2, 1.6, 2.0, 2.4, 2.8, and 3.2 mm) in the 2 irrigation groups. For SNI, isthmus levels designated by the same uppercase letters are not significantly different ($P > .05$). For Vibringe sonic irrigation, isthmus levels designated by the same numeric descriptors are not significantly different ($P > .05$). For each isthmus level, irrigation technique (SNI vs the Vibringe) box plots connected by a horizontal bar are not significantly different ($P > .05$).

it may be concluded that the debridement efficacy in debriding a clinically challenging system such as the MB canal of maxillary molars is not improved by the use of the Vibringe sonic irrigation technique compared with conventional SNI. Both instrumented canal spaces and noninstrumented isthmus regions are cleared of soft-tissue debris to the same extent using the sonic irrigation device or the conventional SNI technique.

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The authors deny any conflicts of interest related to this study.

Supplementary Material

Supplementary material associated with this article can be found in the online version at www.jendodon.com (http://dx.doi.org/10.1016/j.joen.2012.05.009).

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